BIOASSESSMENT REPORT

RAPID BIOASSESSMENT OF THE

BRUSH CREEK WATERSHED

USING BENTHIC MACROINVERTEBRATES

May 2000
October 2000

For the
Soil and Water Conservation District of
Owen County, Indiana

Study Conducted By:

Greg R. Bright and Amanda S. Cutler
Commonwealth Biomonitoring
8061 Windham Lake Drive
Indianapolis, Indiana 46214
(317) 297- 7713

TABLE OF CONTENTS

EXECUTIVE SUMMARY

A rapid bioassessment technique was used to determine the ecological health of four sites in the Brush Creek watershed of Owen County, Indiana. The purpose of the study was to document conditions of the watershed prior to implementation of various land treatments by the Owen County SWCD office. The benthic communities of five sites, including a reference site, were sampled during May and October 2000 to provide information on "before treatment" conditions.

All four study sites in the Brush Creek watershed had biotic index values less than the reference site during at least one sampling period. These sites showed "slight" to "moderate" impacts. The differences were due to both degraded habitat and water quality. Water quality impacts were probably from excessive sediment inputs. One site at the upper end of the watershed had a biotic index value much higher than its habitat value during May. This often occurs where nutrient inputs are excessive.

Recommendations to improve the condition of the Brush Creek watershed include bank stabilization using vegetative techniques, limiting access to the stream by livestock, restoring trees along streambanks, and continued biological monitoring to gauge the success of the program after it has been successfully implemented.

INTRODUCTION

This study was conducted to measure the "biological integrity" of Brush Creek in Owen County, Indiana. The stream is a tributary of Mill Creek in the Eel River/White River Basin. Eel River is listed by the Indiana Department of Environmental Management (IDEM) as having seriously degraded water quality due to nonpoint sources of pollution such as excessive sediment and nutrient inputs from runoff [1].

To deal with this problem, the Soil and Water Conservation District office of Owen County sought and received a grant from the Indiana Department of Natural Resources to develop a soil conservation plan to help reduce nonpoint source problems in the stream. Prior to implementing the plan, the SWCD office decided to conduct a benthic study of the stream to document "before treatment" conditions.

Local Setting

Brush Creek is located in the "Central Corn Belt Plain" ecoregion of the Central U.S. [2]. Figure 1 shows the watershed's location in Indiana. The land in the watershed was molded by glacier activity and is relatively flat. The original forests were dominated by beech, maple, oak, and hickory trees but row crop agriculture and livestock grazing are the most common land uses today. About 90% of the watershed is devoted to agricultural uses. Only about 10% remains forested [19]. Figure 2 is a map of the watershed showing land uses.

Little water quality information has been collected in this watershed. IDEM classified Mill Creek as supporting its designated uses for aquatic life but not supporting its recreational uses due to E. coli contamination [7]. Cataract Lake downstream from Mill Creek has a fish consumption advisory based on low-level mercury contamination [23].

Figure 1.

Brush Creek / Mill Creek Area

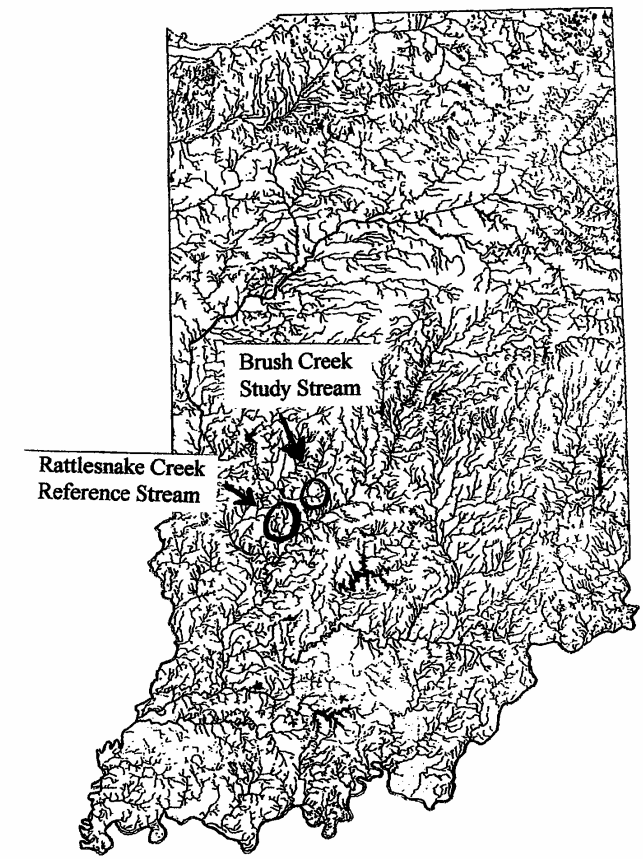
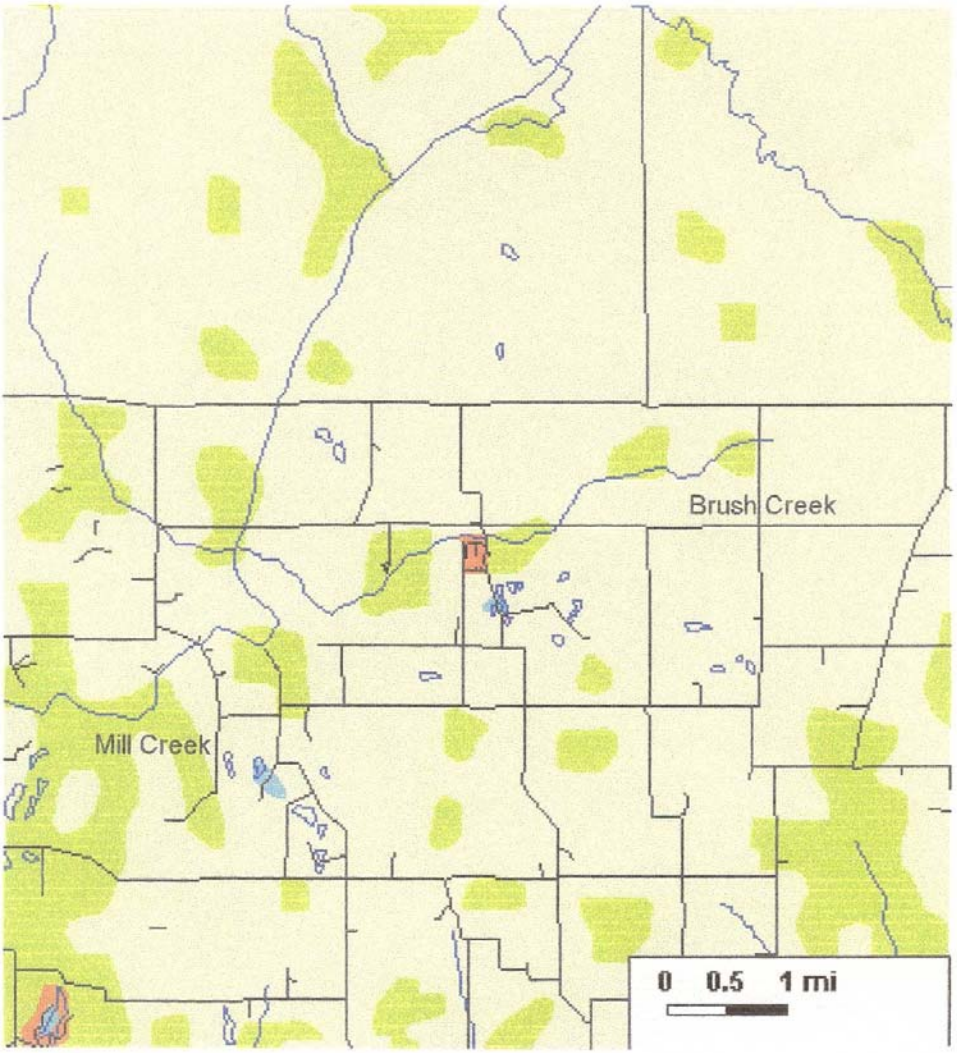


Figure 2.

Land Uses in the Watershed

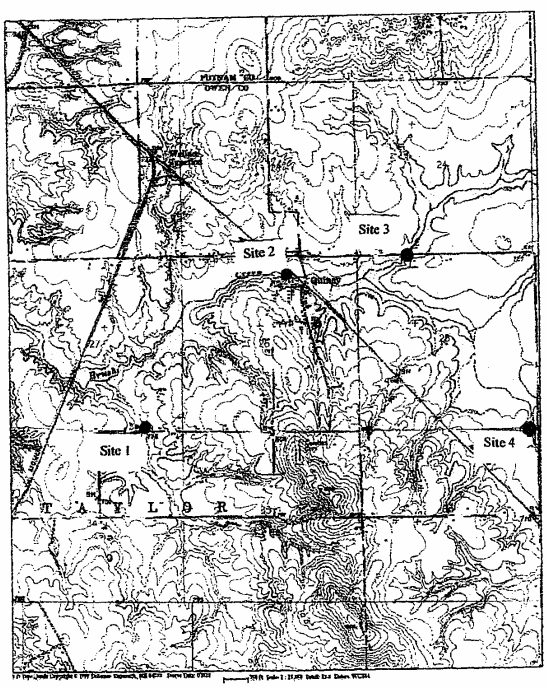
Green is forested, red is urban, yellow is agricultural



Five sampling sites were chosen for this study. All of the study and reference streams are "first order" or "second order" streams. Watershed areas of each site [18] and their locations are shown below:

Site 1	Tributary at CR 1050 N	8 km^2 (3 mi^2)
Site 2	Brush Creek at CR 325 E	23 km^2 (9 mi^2)
Site 3	Brush Creek at CR 1150 N	12 km^2 (5 mi^2)
Site 4	Tributary at CR 450 E	8 km^2 (3 mi^2)
Site 5	Rattlesnake Creek (Reference Site)	38 km^2 (15 mi^2)

Figure 3
Study Sites



METHODS

Because they are considered to be more sensitive to local conditions and respond relatively rapidly to environmental change [3], benthic (bottom-dwelling) organisms were used to document the biological condition of each stream. The U.S. Environmental Protection Agency (EPA) has recently developed a "rapid bioassessment" protocol [4] which has been shown to produce highly reproducible results that accurately reflect changes in water quality. We used EPA's Protocol III to conduct this study. Protocol III requires a standardized collection technique, a standardized subsampling technique, and identification of at least 100 animals from each site to the genus or species level from both "study sites" and a "reference site." CPOM (Coarse Particulate Organic Matter) samples were collected and analyzed to determine the percentage of shredder organisms.

Reference Site

The aquatic community of a reference site is compared to that of each study site to determine how much impact has occurred. The reference site should be in the same "ecoregion" as the study sites and be approximately the same size. It should be as pristine as possible, representing the best conditions possible for that area.

A fisheries study conducted in the 1980s found that Rattlesnake Creek in Owen County had one of the least impacted aquatic communities in Indiana [20]. The stream also has a drainage area which is similar to the study sites and lies only a few miles to the west, in the same ecoregion. Therefore, Rattlesnake Creek was used as the basis of comparison for all other sites in the study.

Habitat Analysis

Habitat analysis was conducted according to Ohio EPA methods [21]. In this technique, various characteristics of a stream and its watershed are assigned numeric values. All assigned values are added together to obtain a "Qualitative Habitat Evaluation Index." The highest value possible with this habitat assessment technique is 100.

Water Chemistry

Water chemistry measurements were made at each study site on the same day that macroinvertebrate samples were collected. Dissolved oxygen was measured by the membrane electrode method. The pH measurements were made with a Cole-Parmer pH probe. Conductivity was measured with a Hanna Instruments meter. Temperature was measured with a mercury thermometer. All instruments were calibrated in the field prior to measurements.

Macroinvertebrate Sample Collection

Benthic sampling occurred on May 15, 2000 and again on October 14, 2000. These two sampling periods represent stream conditions in spring when crops are being planted and autumn, after a full growing season has been completed.

Samples were collected by kicknet from riffle habitat where current speed was 20-30 cm/sec. Riffles were used because they were the most important benthic habitat present at all study sites. The kicknet was placed immediately downstream from the riffle while the sampler used a hand to dislodge all attached benthic organisms from rocks upstream from the net. The organisms were swept by the current into the kicknet and subsequently transferred to a white pan. Each sample was examined in the field to assure that at least 100 organisms were collected at each site. In addition, each site was sampled for organisms in CPOM (coarse particulate organic matter, usually consisting of leaf packs from fast-current areas). All samples were preserved in the field with 70% ethanol. A duplicate sample was collected at one site for quality assurance purposes.

Laboratory Analysis

In the laboratory, a 100 organism subsample was prepared from each site by evenly distributing the whole sample in a white, gridded pan. Grids were randomly selected and all organisms within grids were removed until 100 organisms had been selected from the entire sample.

Each animal was identified to the lowest practical taxon (usually genus or species). As each new taxon was identified a representative specimen was preserved as a "voucher." All voucher specimens have been deposited in the Purdue University Department of Entomology collection.

RESULTS

Aquatic Habitat Analysis

When the Ohio EPA habitat scoring technique was used, the following aquatic habitat values were obtained for each site in the study:

	Score	% of Reference
Tributary (Site 1)	68	83
Brush Creek (Site 2)	61	74
Brush Creek (Site 3)	72	88
Tributary (Site 4)	41	50
Rattlesnake Creek (Site 5)	82	100

The maximum value obtainable by this scoring technique is 100, with higher values indicating better aquatic habitat. Sites with lower habitat values normally have lower biotic index values as well. Details of the habitat scores for each site are shown in the appendix.

The scores indicate that the lowest aquatic habitat value in this study was at site 4 (a small tributary at CR 450 E in the southeastern part of the watershed). Habitat at site 4 was hampered by a paucity of stable bottom substrate and instream cover, by a lack of any riparian buffer zone, and by its very small drainage area.

Water Quality Measurements
May 18, 2000

	D.O. mg/l	pH SU	Cond. uS	Temp. (C)
Site 1 (Tributary) Time = 3:55 p.m.	6.8	7.6	400	19.5
Site 2 (Brush Creek) Time = 4:10 p.m.	7.7	7.4	400	19.5
Site 3 (Brush Creek) Time = 4:25 p.m.	8.2	7.7	400	17.5
Site 4 (Tributary) Time = 4:50 p.m.	10.8	7.6	300	18.5
Site 5 (Rattlesnake Creek) Time = 3:20 p.m.	8.4	7.6	200	18.0

October 13, 2000

	D.O. mg/l	pH SU	Cond. uS	Temp. (C)
Site 1 (Tributary) Time = 3:00 p.m.	13.8	7.8	260	10.5
Site 2 (Brush Creek) Time = 3:45 p.m.	9.7	7.9	260	10.5
Site 3 (Brush Creek) Time = 3:30 p.m.	9.0	7.9	90	11.0
Site 4 (Tributary) Time = 3:20 p.m.	10.0	7.9	250	11.0
Site 5 (Rattlesnake Creek) Time = 1:45 p.m.	11.4	8.3	210	11.5

D.O. = Dissolved Oxygen
Cond. = Conductivity
Temp. = Temperature in Degrees Centigrade

Table 1.
Rapid Bioassessment Results - Brush Creek Watershed
May 2000

	Site #				
	1	2	3	4	5
Chironomidae (Midges)					
Cricotopus trifascia	1	2		1	
C. bicinctus					2
Orthocladius obumbratus	9				
Parametriocnemus lundbecki	18	19		7	11
Tanytarsus glabratus		2			
Polypedilum fallax				4	
P. convictum		4			
P. illinoense		2			
P. scalaenum				2	
Psectrocladius psilopterus				2	
Thienemannimyia gr.		4			2
Ablabesmyia sp.					12
Sympothastia sp.					1
Simuliidae (Blackflies)				6	7
Empididae (Danceflies)		1			
Tipulidae (Craneflies)					
Antocha sp.	1			3	1
Ephemeroptera (Mayflies)					
Stenonema femoratum	1				
S. vicarum					4
Heptagenia sp.			3	6	
Isonychia sayi					4
Baetis brunneicolor			2	3	1
B. amplus			1		
B. tricaudatus			4		
B. intercalaris				1	1
Trichoptera (Caddisflies)					
Cheumatopsyche spp.		3		2	1
Polycentropus sp.					1
Neureclipsis sp.					1
Cyrnellus fraternus					4
Limnephilus sp.	1				
Ironoquia sp.				1	
Megaloptera (Alderflies)					
Chauliodes sp.					3

Table 1 (continued)
Rapid Bioassessment Results - Brush Creek Watershed
May 2000

	Site #				
	1	2	3	4	5
Plecoptera (Stoneflies)					
Nemoura venosa	1	2	2	2	38
Perlesta placida		13	7	2	
Agnetina sp.		2			2
Isoperla minuta		2	2	8	
Haploperla sp.				2	
Odonata (Dragonflies)					
Anax sp.				1	
Coleoptera (Beetles)					
Stenelmis crenata	7	2	3	5	
Stenelmis larvae	42	2	6	11	
Optioservus sp.		2		4	
Psephenus herricki					2
Berosus sp.					1
Dystiscus sp.			2		
Isopoda (Pillbugs)					
Lirceus fontinalis	18	14	65	20	
Gastropoda (Snails)					
Physella gyrina		20	1	4	
Gyraulus spp.				1	
Decapoda (Crayfish)					
Orconectes sp.	1		1	1	
Turbellaria (Flatworms)		1			
Oligochaeta (Worms)					
Tubificidae		3			1
Lumbricidae			1	1	
Total	100	100	100	100	100

Table 2. Data Analysis for 5/00 Samples

METRICS

	Site # 1	2	3	4	5
# of Genera	10	17	11	22	20
Biotic Index	5.7	6.2	6.6	5.1	3.5
Scrapers/Filterers	51	8.7	13	3.5	0.5
EPT/Chironomids	0.1	0.7	21	1.7	2.0
% Dominant Taxon	49	20	65	20	38
EPT Index	3	5	5	8	9
Community Loss Index	1.5	0.8	1.5	0.5	0.0
% Shredders	1	6	6	12	50

SCORING

	Site # 1	2	3	4	5
# of Genera	2	6	2	6	6
Biotic Index	4	2	2	4	6
Scrapers/Filterers	6	6	6	6	6
EPT/Chironomids	0	2	6	6	6
% Dominant Taxon	0	6	0	6	2
EPT Index	0	2	2	6	6
Community Loss Index	4	4	4	4	6
% Shredders	0	0	0	2	6
TOTAL	16	28	22	40	44
% of Reference	36	64	50	91	100
Impairment Category	M	S	M	N	N

N = NONE S = SLIGHT M = MODERATE Sv = SEVERE

Table 3.
Rapid Bioassessment Results - Brush Creek Watershed
October 2000

	Site #				
	1	2	3	4	5
Chironomidae (Midges)					
Cricotopus intersectus	2	1		4	
C. bicinctus	5	1			2
Orthocladius obumbratus	3			1	
Heterotrissocladius marcidus		1		4	
Tanytarsus guerulus				1	
Polypedilum convictum	1				
Rheotanytarsus exiguus		3			
Thienemannimyia gr.	1				
Simuliidae (Blackflies)	1	1		24	
Tipulidae (Craneflies)					
Tipula spp.	1			1	2
Ephemeroptera (Mayflies)					
Stenonema femoratum	1	52	6	5	6
S. vicarium					8
Stenacron interpunctatum		13	6	1	2
Heptagenia sp.		1			
Isonychia sayi					12
Baetis propinquus				1	
B. flavistriga	4	4	2		1
B. brunneicolor				1	
Caenis latipennis		2			4
Baetisca spp.					1
Ephemera simulans					1
Trichoptera (Caddisflies)					
Cheumatopsyche spp.	4	9		18	16
Hydropsyche betteni					7
Chimarra obscura					4
Ceraclea spp.				1	
Helicopsyche borealis					2
Megaloptera (Alderflies)					
Chauliodes sp.					3

Table 3 (continued)
Rapid Bioassessment Results - Brush Creek Watershed
October 2000

	Site # 1	2	3	4	5
Odonata (Dragonflies)					
Enallagma spp.				1	
Somatochlora spp.				2	
Coleoptera (Beetles)					
Stenelmis crenata				1	
Stenelmis larvae	1	2		6	
Dubiraphia larvae	5				
Psephenus herricki					12
Isopoda (Pillbugs)					
Lirceus fontinalis	69	1	83	11	1
Caecidotea spp.		2		2	
Gastropoda (Snails)					
Physella gyrina		2		5	
Ferrissia spp.				1	
Birgella subglosa		1			
Elimia livescens					13
Pelecypoda (Clams)					
Pisidium spp.		2		7	
Amphipoda (Scuds)					
Hyalella azteca					2
Hirudinea (leeches)		1	1		
Turbellaria (Flatworms)					
Oligochaeta (Worms)					
Tubificidae	1	1	1	2	1
Lumbricidae			1		
Total	100	100	100	100	100

Table 4. Data Analysis for 10/00 Samples

METRICS

	Site # 1	2	3	4	5
# of Genera	13	18	7	21	19
Biotic Index	7.7	7.2	7.7	6.9	4.7
Scrapers/Filterers	1.8	6.1	12	0.5	1.2
EPT/Chironomids	0.8	14	14	2.7	33
% Dominant Taxon	69	52	83	24	16
EPT Index	3	6	3	6	11
Community Loss Index	0.9	0.6	1.7	0.5	0.0
% Shredders	35	2	26	2	5

SCORING - October

	Site # 1	2	3	4	5
# of Genera	4	6	0	6	6
Biotic Index	0	0	0	2	6
Scrapers/Filterers	6	6	6	4	6
EPT/Chironomids	0	4	4	0	6
% Dominant Taxon	0	0	0	4	6
EPT Index	0	2	0	2	6
Community Loss Index	4	4	2	4	6
% Shredders	6	4	6	4	6
TOTAL	20	26	18	26	48
% of Reference	42	54	38	54	100
Impairment Category	M	S	M	S	N

N = NONE S = SLIGHT M = MODERATE Sv = SEVERE

Summary of Aquatic Community Index Scores (Normalized to 100)

	Site 1	Site 2	Site 3	Site 4	Watershed Average
May	**36**	**64**	**50**	**91**	**60**
October	**42**	**54**	**38**	**54**	**47**

QUALITY ASSURANCE DUPLICATE RESULTS

Rattlesnake Creek

Sample 1 collected by Amanda Cutler
Sample 2 collected by Greg Bright
Sample Date - 10/14/00

	Actual Data	
	Sample 1	Sample 2
Total Genera	19	17
EPT Genera	11	7
Scrapers/Filterers	1.2	0.7
% Dominant Taxon	16	18
EPT/Chironomids	33	28
Community Loss Index	0.0	0.4
Hilsenhoff Biotic Index	4.7	4.6
% Shredders	5	5

	IBI Scores	
	Sample 1	Sample 2
Total Genera	6	6
EPT Genera	6	4
Scrapers/Filterers	6	6
% Dominant Taxon	6	6
EPT/Chironomids	6	6
Community Loss Index	6	6
Hilsenhoff Biotic Index	6	6
% Shredders	6	6
Total Score	48	46

Mean Site Score = 47
Each duplicate is within 10% of the mean
Both scores indicate "no impairment"

The quality assurance duplicates provided strong evidence that the bioassessment technique produced reproducible data during this sampling period.

DISCUSSION

Chemical parameters measured at each site indicate that dissolved oxygen (D.O.), pH, temperature, and conductivity fell within acceptable ranges for most forms of aquatic life. Dissolved oxygen was considerably higher or lower than saturation at site 1 during both sampling periods. This often indicates the presence of a dense algal community in a stream. The algae use oxygen during periods of low light and produce excessive oxygen during periods of intense light exposure. Algae become much more abundant when excessive nutrients (nitrogen and phosphorus) are present in the stream.

A total of 41 macroinvertebrate genera were collected at the five sites during May and 40 were collected during October. The pollution intolerant groups Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies) were relatively scarce at site 1 but abundant elsewhere. Aquatic pillbugs were especially common at site 3 during both sampling seasons.

Tables 2 and 4 show how the aquatic communities at the five study sites compared to that of the reference site. Impacted sites are shown graphically in Figure 3. The stream's impairments ranged from "none" to "moderate." One of the surprises of the study was that, despite its low habitat quality, the biotic index value for site 4 during the May sampling period was very high. The significance of this finding is discussed in more detail below.

Figure 4 shows the normal relationship of biotic index scores to habitat values (a linear relationship according to [4]). The figure also shows a range of plus or minus 10% to account for a certain amount of measurement variability. When biotic index values fall outside this range, the site typically has degraded water quality. Figure 4 indicates that none of the study sites had biotic values within the range expected from its measured habitat value. Therefore, the lower than expected biotic values are both water quality and habitat degradation. The largest deviation from the expected value occurred at sites 1 and 3, in the Brush Creek headwaters.

The October biotic index values were lower than the values in May at three of the four study sites. However, except at site 4, the differences were not especially large and did not result in a significant change in impairment category. Therefore, a single sampling season should be adequate to characterize the biological condition of Brush Creek in future studies.

Figure 3.
Degrees of Biological Impairment in the Brush Creek Watershed

Yellow = Slight Impairment
Orange = Moderate Impairment

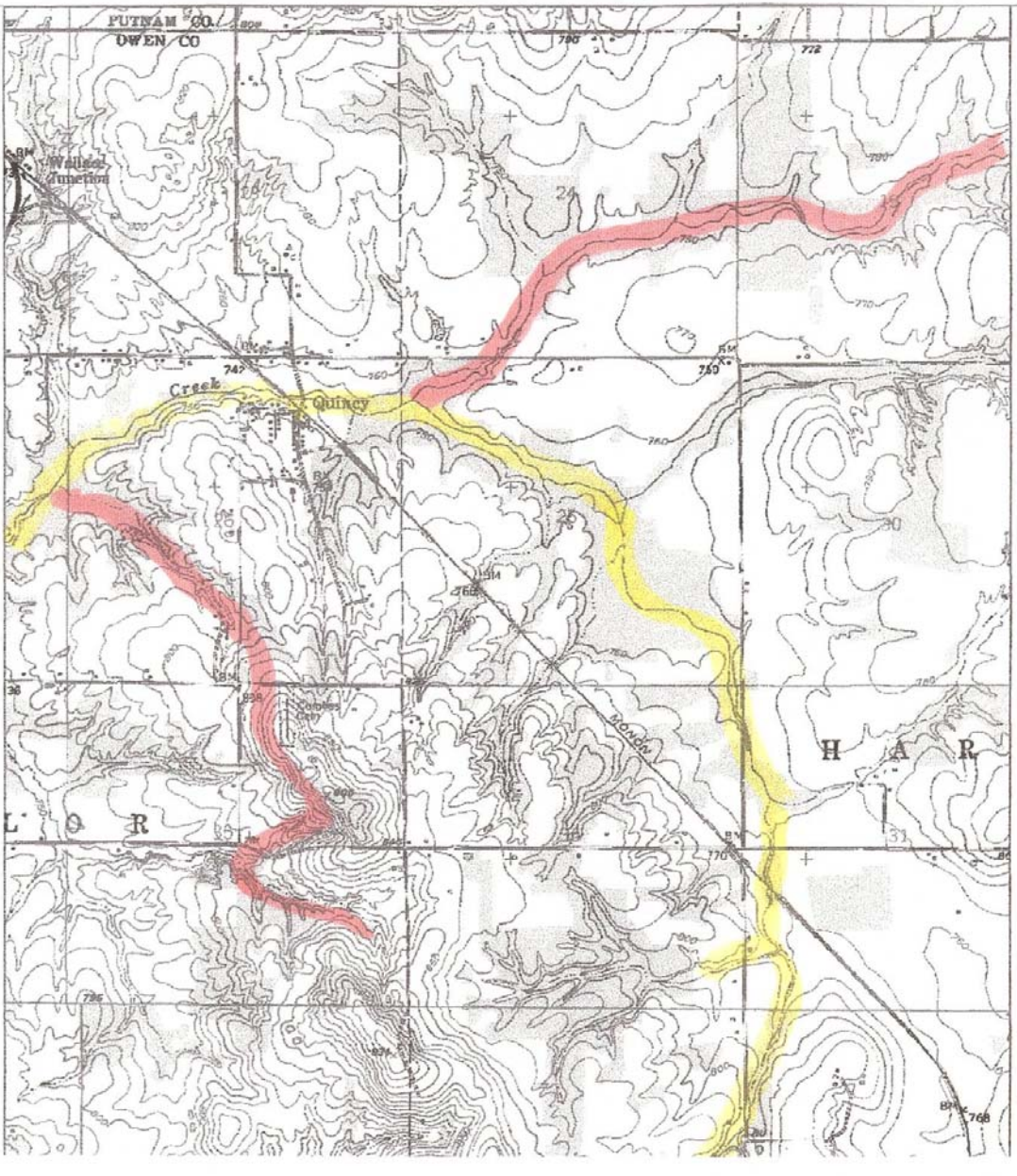


Figure 4.

The normal relationship between habitat and biotic index score is shown below. Sites falling outside the normal relationship (plus or minus 10%) are probably affected by degraded water quality.

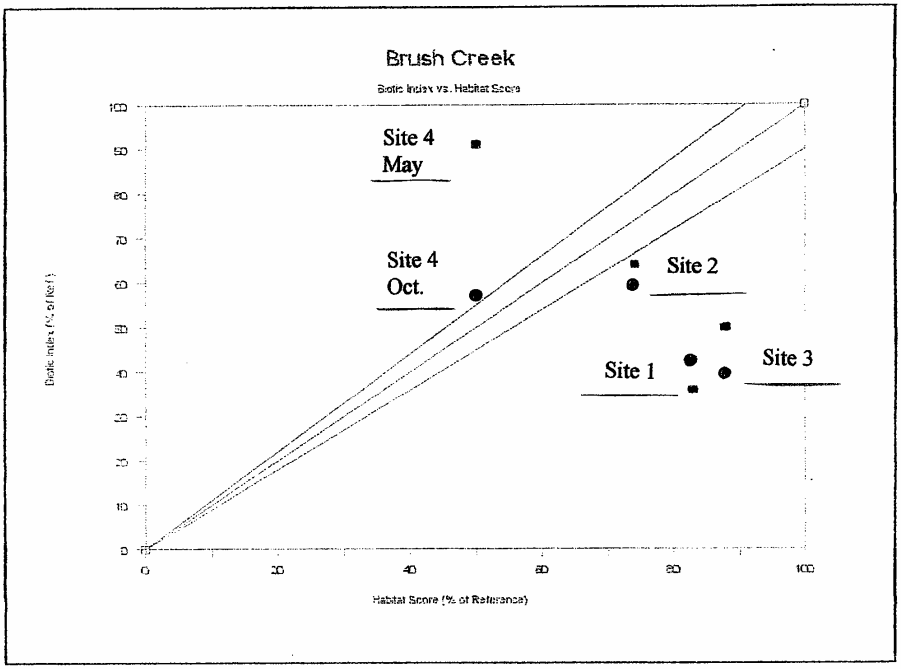


Table 4 shows sediment-tolerance values for many of the commonly collected animals in these streams. The proportion of sediment and turbidity-intolerant forms was much higher at the reference site than at any of the study sites. These results indicate that sediment-related impairment may be contributing to the water quality problems in the Brush Creek watershed. This is especially true at site 1, where almost no sediment-intolerant forms of life were found during either study period.

Table 4. Sediment-Intolerant Species Observed
(Literature references to the species as an indicator are shown in brackets)

Stenonema vicarium	[10] [15]
Stenonema tripunctatum	[10][15]
Plecoptera	[10]
Antocha spp.	[10]

	May	October
% of Sediment-Intolerant Organisms at the Reference	45%	18%
% of Sediment-Intolerant Organisms at the Study Sites		
Site 1	3%	1%
Site 2	19%	0%
Site 3	11%	0%
Site 4	17%	1%

The observation of a biotic index value much higher than its habitat value at site 4 during May (upper Brush Creek at CR 450 E) has been observed in other studies where excessive nutrient inputs are known to occur [4]. Nutrient enrichment will artificially sustain a more diverse fauna than would normally be expected by its habitat quality. However, this effect reaches a threshold, beyond which a drastic decrease in biological condition often occurs. The biotic index value for site 4 declined significantly during the October sampling period.

There is also evidence from this study that Brush Creek may periodically have excessive inputs of oxygen-consuming substances such as manure or sewage. This was especially true during October, when the Hilsenhoff Biotic Index (very sensitive to dissolved oxygen changes) fell in the poor water quality range at three of the four study sites.

RECOMMENDATIONS

1. **Concentrate best management practices in the tributary watersheds where water quality is worst (especially in the headwaters at sites 1 and 3).**

2. **Work toward continued protection of the vegetative buffer zone along the stream corridors. Tree plantings along streams should be encouraged to provide shade.**

3. **Discourage channelization of the stream. Minimizing channelization allows the streams to retain a natural channel that enhances aquatic habitat.**

4. **Discourage direct access to the streams by livestock. Large numbers of livestock can trample stream banks, decreasing the ability of streamside vegetation to filter out pollutants and hastening erosion.**

5. **Consider a bank stabilization program on some of the headwater streams. Use vegetative stabilization techniques rather than rip-rap whenever possible.**

6. **Continue to monitor the watershed every three to five years to determine whether conditions improve. This study indicates that a single sampling season is enough to provide useful information for this purpose.**

7. **Continue to encourage volunteer monitoring in the watershed. Such programs provide invaluable educational opportunities and give participants a sense of ownership in the water quality improvements observed over the years.**

LITERATURE CITED

1. Indiana Department of Environmental Management. 1989. Nonpoint Source Water Pollution Assessment Report. Office of Water Management, Indianapolis, IN.

2. Omernik, J.M. and A.L. Gallant. 1988. Ecoregions of the Upper Midwest States. U.S. EPA Environmental Research Laboratory, Corvallis, OR. EPA/600/3-88/037.

3. Hynes, H.B.N. 1970. The ecology of running waters. Univ. of Toronto Press, Toronto. 555 pp.

4. Plafkin. J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers. U.S. EPA Office of Water, Washington, D.C. EPA/444/4-89-001.

5. Simon, T.P. and R. Dufour. 1998. Development of Index of Biotic Integrity Expections for the Ecoregions of Indiana. V. Eastern Corn Belt Plain. EPA 905/R-96/004. EPA Publication Distribution Center, Cincinnati OH. 68 pp. plus appendices

7. Indiana Department of Environmental Management, 1996. Indiana 305(b) Report 1994-95. Office of Water Management, Indianapolis, IN.

7. Simpson, K.W. and R.W. Bode. 1980. Common larvae of chironomidae (diptera) from New York State streams and rivers. Bull. No. 439. NY State Museum, Albany, NY.

8. Schuster, G.A. and D.A. Etnier. 1978. A manual for the identification of the larvae of the caddisfly genera Hydropsyche and Symphitopsyche in Eastern and Central North America. U.S. EPA Environmental Support Laboratory, Cincinnati, OH (EPA-600/4-78-060.

9. Lenat, D.R. 1984. Agriculture and stream water quality: a biological evaluation of erosion control practices. Environ. Manag. 8:333-344.

10. Roback, S.S. 1974. Insects (Arthropoda:Insecta). In Hart, C.W. and S.L.H. Fuller, eds., Pollution ecology of freshwater invertebrates. Academic Press, New York, 389 pp.

11. Winner, R.M., M.W. Boesel, and M.P. Farrell. 1980. Insect community structure as an index of heavy metal pollution in lotic ecosystems. Can. J. Fish. Aq. Sci. 37:647-655.

12. Whiting, E.R. and H.F. Clifford. 1983. Invertebrates and urban runoff in a small northern stream, Edmonton, Alberta, Canada. Hydrobiologia 102:73-80.

13. Gammon, J.R. 1970. The effect of inorganic sediment on stream biota. U.S. EPA Water Quality Office, Washington, D.C.

14. Homoya, M.A. et al. 1985. The natural regions of Indiana. Proc. Ind. Acad. Sci. 94:245-268.

15. Lewis, P.A. 1974. Taxonomy and ecology of Stenonema mayflies. U.S. EPA Environmental Support Laboratory, Cincinnati, OH.

16. Jones, R.C. and C.C. Clark. 1987. Impact of watershed urbanization on stream insect communities. Water Res. Bull. 23: 1047-1055.

17. Hilsenhoff, W.L. 1982. Using a biotic index to evaluate water quality in streams. Tech. Bull. #132, Wisc. Dept. of Nat. Resourc., Madison WI. 21 pp.

18. Hoggatt, R.E. 1975. Drainage areas of Indiana Streams. U.S. Geological Survey, Water Resources Division, Indianapolis, IN.

19. Indiana Geological Survey, 2000. Land use data for Indiana. Internet file (www.adamite.igs.indiana.edu).

20. Fisher, W.L. and J.R. Gammon. 1983. An annotated list of the fishes of Eagle, Stotts, and Rattlesnake Creeks in Central Indiana. Proc. Ind. Acad. Sci. 92:171-182.

21. Ohio EPA. 1987. Biological criteria for the protection of aquatic life. Vol. III. Standardized biological field sampling and laboratory methods. Div. Water Qual. Monit. Assess., Columbus, OH.

22. Penak, R.W. 1989. Freshwater invertrebrates of the United States. Third Edition. John Wiley & Sons, NY.

23. Indiana State Department of Health, 2000. Indiana fish consumption advisory. Environmental Epidemiology Section, Indianapolis IN.

Habitat Scoring Results

	Site 1	Site 2	Site 3	Site 4	Site 5
SUBSTRATE	10	8	10	7	15
COVER	8	8	10	3	11
CHANNEL	12	11	13	7	14
RIPARIAN	15	11	16	8	16
POOL/RIFFLE	12	10	11	7	12
GRADIENT	6	6	6	4	6
DRAINAGE AREA	5	7	6	5	8
TOTAL	68	61	72	41	82

COMMONWEALTH BIOMONITORING
Macroinvertebrate Identification Literature

Barr, C.B. and J. B. Chapin. 1988. The aquatic Dryopoidea of Louisiana. Tulane Studies Zool. Bot. 26:89-163

Bednarik, A.F. and W.P. McCafferty. 1977. A checklist of the stoneflies or Plecoptera of Indiana. Great Lakes Entomol. 10:223-226.

Bednarik, A.F. and W.P. McCafferty. 1979. Biosystematic revision of the genus Stenonema. Can. Bull. Fish. Aquat. Sci. 201:1-73

Burch, J.B. 1982. Freshwater snails of North America. EPA-600/3-82-026. USEPA, Cincinnati, OH.

Burks, B.O. 1953. The mayflies or Ephemeroptera of Illinois. Bull. Ill. Nat. Hist. Survey 26(1).

Cummings, K.S. and C.A. Mayer. 1992. Field guide to freshwater mussels of the Midwest. Ill. Nat. Hist. Surv. Manual 5. Champaign, IL.

Edmunds, G.F., S.L. Jensen, and L. Berner. 1976. The mayflies of North and Central America. Univ. of Minn. Press.

Epler, J.H. 1992. Identification manual for the larval Chironomidae of Florida. Florida Dept. Envir. Reg., Tallahassee, Florida.

Fitzpatrick, J.F. 1983. How to know the freshwater crustacea. W.C. Brown Co., Dubuque, Iowa.

Frison, T.H. 1935. The stoneflies or Plectoptera of Illinois. Bull. Ill. Nat. Hist. Surv., Vol. 20. Urbana, IL.

Hilsenhoff, W.L. (undated). Aquatic insects of Wisconsin. Geol. Nat. Hist. Survey, Madison, WI.

Hilsenhoff, W.L. 1984. Identification and distribution of Baetisca nymphs in Wisconsin. Great Lakes Entomol. 17:51-52.

Kondratieff, B.C. and J.R. Voshell. 1984. The North and Central American species of Isonychia. Trans. Amer. Entomol. Soc. 110:129-244.

Lawson, H.R. and W.P. McCafferty. 1984. A checklist of Megaloptera and Neuroptera of Indiana. Great Lakes Entomol. 17:129-131.

Mackie, G.L. and D.G. Huggins. 1983. Sphaeriacean clams of Kansas. Tech. Publ. No. 14, State Biological Survey of Kansas, Lawarence, KS.

McCafferty, W.P. 1975. The burrowing mayflies of the United States. Trans. Amer. Entomol. Soc. 101:447-504.

Merritt, R.W. and K.W. Cummins (eds.) 1995. An introduction to the aquatic insects of North America (Third Edition). Kendall/Hunt Publishing Co., Dubuque, Iowa.

Morihara, D.K. and W.P. McCafferty. 1979. The Baetis larvae of North America. Trans. Amer. Entomol. Soc. 105:139-221.

Page, L.M. 1985. The crayfishes and shrimps of Illinois. Ill. Nat. Hist. Surv. Vol 33, Champaign, IL.

Pennak, R.W. 1989. Freshwater invertebrates of the United States (Third Edition). John Wiley and Sons, NY.

Schmude, K.L. and W.L. Hilsenhoff. 1986. Biology, ecology, larval taxonomy, and distribution of Hydropsychidae in Wisconsin. Great Lakes Entomol. 19:123-145.

Schuster, G.A. and D.A. Etnier. 1978. A manual for the identification of the larvae of the caddisfly Hydropsyche and Symphitopsyche in eastern and central North America. EPA-600/4-78-060. USEPA, Cincinnati, OH.

Simpson, K.W. and R.W. Bode. 1980. Common larvae of Chironomidae from New York State streams and rivers. Bull. No. 439, NY State Education Dept., Albany, NY.

Stewart, K.W. and B.P. Stark. 1984. Nymphs of North American Perlodinae genera. Great Basin Naturalist 44:373-415.

Waltz, R.D. and W.P. McCafferty. 1983. The caddisflies of Indiana. Purdue Agric. Exper. Sta. Res. Bull. 978. West Lafayette, IN.

Wiederholm, T. (ed.) 1983. Chironomidae of the Holarctic region. Part 1. Larvae. Entomol. Scand. Suppl. 19.

BIOASSESSMENT SUMMARY
BRUSH CREEK - OWEN COUNTY

Purpose

To measure the water quality of Brush Creek in Owen County, Indiana by looking at the kinds of animals which live there. Another aim is to diagnose problems and recommend solutions.

Degraded Aquatic Habitat

Watershed Characteristics

The watershed land use is primarily agricultural. The small town of Quincy lies in the watershed.

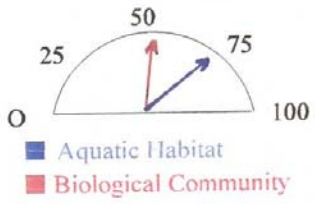
Results

Brush Creek has a biological community which is impaired by excessive sediment, nutrients and habitat degradation.

Recommendations

Encourage bank stabilization with vegetative techniques. Plant shading trees along streambanks. Use BMPs to reduce sediment and nutrient inputs.

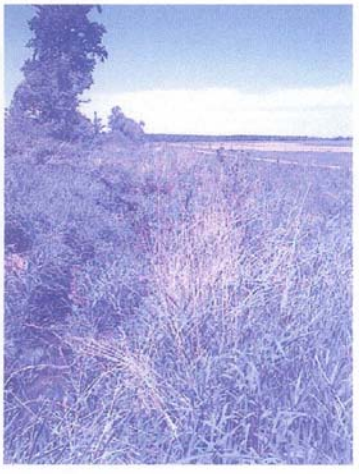
Watershed Gauge
A score of 100 is our goal



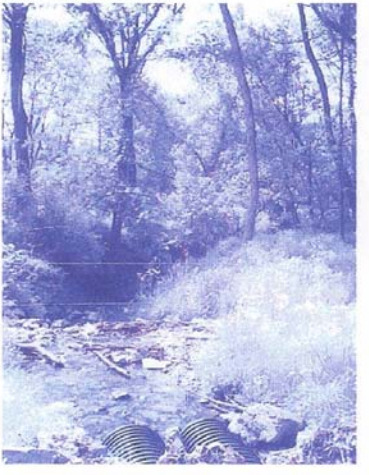
Date: May and October 2000

Study conducted by:

Commonwealth Biomonitoring, Inc.
www.biomonitor.com



Site 4 CR 450 E



Site 1 CR 1050 N

Site 3. CR 1150 N

Site 2 Quincy

Extra Site on CR 450 E

Rattlesnake Creek